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Rapid switching and ultra-responsive nanosensors based on individual shell–core Ga2O3/GaN:Ox@SnO2 nanobelt with nanocrystalline shell in mixed phases

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Abstract

Research on semiconducting oxide nanocrystals will likely remain one of the leading topics in condensed matter physics and advanced functional materials. Looking beyond this field, chemically heterogeneous nanocrystals systems based on mixed phases have been assembled as reported here for shell–core Ga2O3/GaN:Ox@SnO2 nanocables, i.e. long and single crystalline SnO2 belts/wires as core surrounded with a shell composed of GaN:Ox and Ga2O3 nanoparticles. Subsequently, nano- and micro-sensors from an individual shell–core Ga2O3/GaN:Ox@SnO2 nanocable on the chip have been realized via localized maskless growth of metal using dual-beam FIB–SEM instrument. In contrast to pure SnO2 nanowire-based sensor, here fabricated nano- and micro-devices on individual hybrid nano- or micro-cables on chip are quite stable, highly sensitive (the current ratio IUVON/IOFF>104), higher and faster switching in UV photodetection, as well as air/vacuum and temperature sensing capabilities. The SnO2 nano- and microbelts/wires networks were synthesized by the flame transport synthesis and a shell layer composed of Ga2O3/GaN:Ox nanoparticle was deposited on them by magnetron sputtering. The scanning electron microscopy and transmission electron microscopy results revealed that the Ga2O3/GaN:Ox nanocrystallite shells are uniformly deposited on SnO2 networks. The detailed TEM structural studies on the as-grown and annealed structures confirmed that the nanocable is made from mixed phases by an excellent agreement with the standard data for rutile SnO2, amorphous GaN:Ox and monoclinic β-Ga2O3. Herein, we resolve two essential problems regarding the nano-construction of an efficient nanosensor. First, the simplest process fabrication of the highly protected shell–core nanocables with improved electrical properties is achieved by cost-effective synthesis in a controlled

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manner. Second, construction of a non-planar 3D nanoscale double-heterojunctions with a large surface area is realized via an efficient technique. It allows surface protection of nanosensors during its fabrication and operation in different ambient conditions. The developed nanomaterial sparks interest for further studies on different hybrid semiconducting oxides as promising candidates for fabricating multifunctional nano- and micro-sensors and photodetectors.